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# ADAPTIVE WEB-BASED INSTRUCTIONAL SYSTEMS – AN OVERVIEW

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The purpose of this paper is to present an overview of the current status of the discipline of Adaptive Web-based Instructional Systems, emphasizing on research trends and state-of-the-art techniques.

## 1 Introduction

Adaptive Hypermedia is a relatively young research field, which has been established on the intersection of hypermedia systems and adaptive user-interfaces [De Bra et al. 1999a]. In adaptive hypermedia, as in every hypermedia application, there is a structure of nodes and links that connect them. In contrast though to the rest of the hypermedia applications, an adaptive hypermedia system maintains a user model and alters the content, as well as the presentation of the information, contained within the nodes on the fly. Links are also adaptive, that is their presentation and functionality is adjusted as well. The aforementioned sustainable and constantly updated user model is utilized in order to lead the system's user towards new and interesting information and keep him or her away from information that is considered inappropriate or useless. Adaptive Hypermedia Systems have already started being broadly applied in instructional systems, which have certain deficiencies that can be remedied through adaptation techniques.

The structure of the paper is as following: the theoretical underpinnings of adaptive systems is given in section 2, where the concepts of hypermedia systems, web-based instructional systems and their adaptive versions are discussed. Section 3 analyzes the need for the application of adaptation techniques in hypermedia and instructional systems and how this need is covered through adaptive systems. Section 4 performs a classification of the adaptation techniques and describes the structure of an adaptive web-based instructional system.

## 2 Theoretical Underpinnings

We should start by explaining the concepts of this discipline so that the theoretical background of the paper is set. The notion we are dealing with is the Adaptive Web-based Instructional Systems, which stand on the crossroad between Adaptive Hypermedia Systems and Web-based Instructional Systems. Therefore to define the concept of Adaptive Web-based Instructional Systems we will look at the relevant concepts, on which it is based on.

Hypermedia Systems can be defined as [Lowe and Hall 1999]: “An application which uses associative relationships among information contained within multiple media data for the purpose of facilitating access to, and manipulation of, the information encapsulated by the data”. The most well-known and broadly-used category of hypermedia systems are the ones that are deployed on the World Wide Web. Web applications are used in various critical sectors of the modern economy such as e-commerce, e-government and e-learning. Especially in the field of e-learning, there is a massive growth of software systems being developed, leading to a plethora of systems known as Web-based Instructional Systems, or Learning Management Systems or Virtual Learning Environments.

**Web-based Instructional Systems (WBIS)** support and partially automate the required teaching and learning processes for the services of education and training. Examples of such processes are courseware authoring and delivery, classroom management, performing assessment of the learners, course management, and communication between the various actors (learners, teachers, tutors etc.).

Both Hypermedia Systems and Web-based Instructional Systems can be engineered to be adaptive, according to the user needs and profiles. The application of adaptation techniques results in Adaptive Hypermedia Systems and Adaptive Web-based Instructional Systems (AWBIS).

**Adaptive Hypermedia Systems** [De Bra et al. 1999b] are hypermedia systems that maintain some personal user elements in a **user model** and apply this model to adapt certain visible aspects of the system to the user. In other words an AHS must satisfy three criteria: to be a hypermedia system, i.e. to have nodes and links, to maintain a user model, and to be able to adapt the hypermedia according to that model. The elements that can be adapted in an AHS are: a) the

content and the presentation of the information contained within the nodes, on the fly, and b) the links between the nodes.

**Adaptive Web-based Instructional Systems** [Brusilovsky 1998] are a sub-category of AHS. In these systems the user model is replaced by the **learner model**, which maintains the preferences and performance of learners that participate in some learning process.

Figure 1 depicts a macroscopic view of the aforementioned 4 categories of applications, emphasizing on the relationships between them, using an object-oriented visual modeling language, the Unified Modeling Language (UML) [http://www.rational.com/uml]. On one occasion, by considering these categories of applications as classes according to the object-oriented paradigm, web-based instructional systems and adaptive web-based instructional systems are subclasses of hypermedia systems and adaptive hypermedia systems respectively. In that sense they inherit their characteristics. On the other hand hypermedia systems and web-based instructional systems are related to the corresponding adaptive systems with a one-way relationship, stereotyped with “Adaptation”.

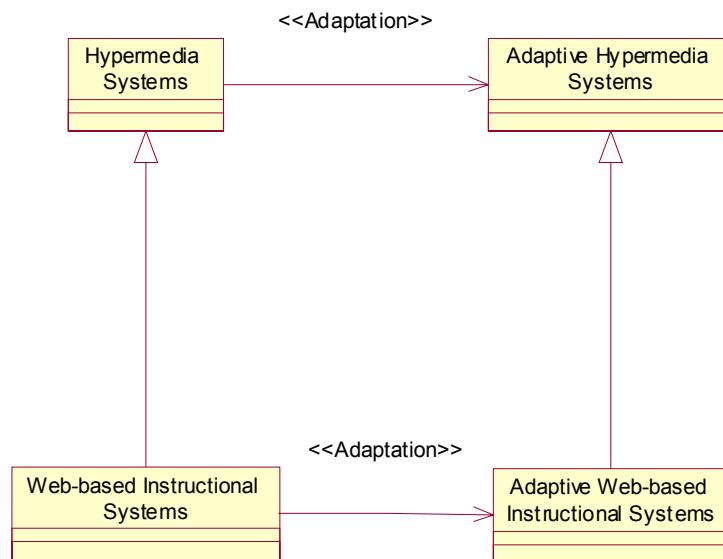


Figure 1 – the 4 classes of applications

### 3 Adaptive web-based instructional systems

Adaptive web-based Instructional Systems are currently a highly active research field and have only during the recent one or two years started appearing as commercial applications. AWBIS are called upon to solve certain problems that originate from the shortcomings of traditional web-based instructional systems and are summarized as following:

- Instructional Systems that are not adaptive suffer from the ubiquitous “lost in hyperspace” problem. According to that, the learners are lost during navigation through the hypermedia content and do not know where they have come from, where they are and where they can lead themselves.
- Too much effort is spent on the learner’s side to comprehend the hypermedia structure, on the expense of the learning process; hence there is a cognitive overload. For example the learner tries too hard to comprehend the functions of the graphical user interface, instead of focusing on the learning content per se.
- They are either too restrictive, effecting in the loss of the user’s flexibility and freedom, or too relaxed, resulting in chaotic structures.
- The idiosyncrasy and diversity of learners, especially concerning their learning styles and performance, causes it impractical and ineffective to treat all the learners in the same way. Instead, each learner should be treated in a personalized way, according to his/her performance, preferences and learning style.
- In cases where the learning process takes place in isolation (e.g. in distance learning), without teacher supervision, the learner must be supported and assisted by the instructional system.

AWBIS are characterized by certain attributes and functions that assist in the direction of solving the above problems. To begin with, AWBIS by adapting their content and links,

leverage the complexity of the hypermedia structure, restraining the navigation and making it easier for the novice users to better orientate and avoid getting lost. On the other hand, they grant expert users enough freedom and flexibility in their navigation, so that they won't feel constrained. Furthermore, they remove the burden imposed on novice users of trying to comprehend the user interface and assist them to focus on the content of the learning material. Finally they fill in the gap caused by the lack of a supervising teacher by guiding users with content and link adaptation and helping them individually, according to their needs and preferences. The ways that all the above are achieved are presented in the following paragraphs.

## 4 adaptation Techniques

The adaptation techniques that are applied in WBIS are originated from 2 different fields: Intelligent Tutoring Systems and Adaptive Hypermedia Systems.

The first category, the Intelligent Tutoring Systems incorporate the following adaptation techniques:

- **curriculum sequencing.** Provides the best possible sequence of learning units and activities (examples, questions, exercises), so that the learner is presented with the optimal path to the learning material. This is the oldest and most popular technique in AWBIS.
- **intelligent analysis of student's solutions and interactive problem solving support.** This technique assists learners with solving problems, doing exercises and assignments etc. During these activities, the learners are supported by the appropriate feedback from the system, after it has processed the final answers. Such problems can vary from a simple question to a complex programming exercise. In contrast to the traditional systems that merely evaluate the correctness of the answer, intelligent systems indicate the exact errors occurred, as well as which pieces of knowledge are missing or have been falsely learned and are responsible for the error. Therefore, intelligent systems provide extensive feedback to the learner while at the same time updating the learner's model.
- **collaboration support.** This technique aims at locating the best possible partner in a working group or an assistant or tutor in a course. It can also help in forming the optimal working groups according to the learner models. This is one of the newest techniques in the field.

As far as the Adaptive Hypermedia Systems are concerned, these incorporate the following adaptation techniques:

- **adaptive presentation.** This technique aims at adapting the web page content, so that it matches the goals, knowledge and other information, stored in the learner model. Therefore in this technique, information is presented in various ways. In a system that utilizes adaptive presentation, web pages are not static, but are dynamically created or assembled piece by piece for each user. For example depending on the learner's level, novice or expert, the system can either present detailed and analytical learning content or only the basic features. Adaptive presentation can be achieved by adding or removing pieces of content, shading pieces, having different versions of pieces, adding explanatory notes, changing the sequence of content etc.
- **adaptive navigation.** This technique aims at supporting the user at maintaining good orientation during navigation, by altering the appearance of visible links and supplying the appropriate links for guiding the learner towards the most interesting and relevant information. Adaptive navigation can be achieved by adding annotations to links, changing their sequence, hiding or deactivating links. The result is an easier choice of links by the learner.

AWBIS utilize the aforementioned techniques from both Intelligent Tutoring Systems and Adaptive Hypermedia Systems. It is emphasized that all of the above techniques are based on the learner model, which is comprised of the goals, the knowledge and other stored information that characterizes the learner. In essence, an AWBIS, in accordance to Adaptive Hypermedia Systems, is comprised of the following [De Bra et al. 1999b]:

- **domain model:** it describes the hypermedia structure of the content and links of the learning content.
- **user model:** it describes the learner information that the AWBIS maintains in a some data storage. It usually contains the representation of the knowledge that the learner has acquired as well as the history of nodes that the learner has visited.
- **teaching model:** it contains pedagogical rules that define the combination of the domain model with the learner model so that the adaptation can be performed.

- **adaptive engine:** it executes the adaptation for every individual user, by adapting or dynamically producing the content of the nodes and the destination and class of the links. The adaptive engine is usually rule-based.

AWBIS have been making their appearance as either research attempts or as commercial products. Some of the most important approaches are presented in [Soller et al. 2000], [Dunkel 1999], [Moore et al. 1997], [Brusilovsky 1996].

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